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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 723

Contribution from the Bureau of Entomology
L. O. Howard, Chief
and the Federal Horticultural Board, C. L. Marlatt, Chairman

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THE PINK BOLLWORM[1] WITH SPECIAL REFERENCE TO STEPS TAKEN BY THE DEPARTMENT OF AGRICULTURE TO PREVENT ITS ESTABLISHMENT IN THE UNITED STATES.

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HISTORICAL.

In 1842 the superintendent of the Government cotton plantations at Broach, India, sent specimens of a very destructive cotton insect to the distinguished English entomologist, W. W. Saunders. The specimens were described as a new species, *Depressaria* (now *Pectinophora*) *gossypiella*, by Mr. Saunders in a paper presented to the Entomological Society of London on June 6, 1842 (9).[2] This is the first published record concerning the insect which is now attracting so much attention in the principal cotton-producing countries of the world.

For 61 years after the publication of Saunders's description no published statement regarding the pink bollworm was issued. In 1904, however, an article was issued by J. Vosseler (10) regarding the great injury done by the insect in German East Africa. Within

[1] *Pectinophora gossypiella* Saunders; order Lepidoptera, family Gelechiidae.
[2] Numbers in parentheses refer to "Literature cited," p. 27.

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the next few years several additional articles dealing with the problem caused by the pest in German East Africa appeared. In 1909 D. T. Fullaway (5) published an account of the pink bollworm and its relation to cotton culture in the Hawaiian Islands, stating that it appeared to have been introduced from India within a very few years.

Only a few more or less technical papers were published from 1909 to 1913. Since the latter date a considerable literature has been built up, consisting largely of papers emanating from Egypt, where the pest has attracted increasing attention.

ORIGINAL HOME.

The original home of the pink bollworm is probably India and possibly Southern Asia generally, and its original host plants were the wild and cultivated cottons of that region. If this natural range of the insect extended to Africa it must have been limited to Central Africa and at least it did not extend to the Nile Valley region where cotton has been an important cultivated crop for a century or more. The occurrence of the insect in Egypt is apparently traced definitely to large shipments of seed cotton or imperfectly ginned cotton from India in 1906–7, and the spread of the insect from the points in the lower Delta near Alexandria, where this cotton was sent for reginning, throughout the Delta, and ultimately throughout Egypt, is so circumstantial as to leave no doubt as to the entry of the insect at that time into Egypt. With the first occurrence of the insect in Egypt it was confused more or less with other insects commonly found in cotton bolls in that country, and this confusion led to a statement by Dudgeon (4) that this insect had probably been in Egypt for many years. The careful investigation of the situation and determination of original points of infestation and spread by expert entomologists in the employ of the British and Egyptian Governments have fully disproved this early surmise and pointed out the circumstantial introduction of the insect into Egypt as noted.

As already noted, the pink bollworm has been recorded as a cotton pest in India since 1842, and the original report made by the Superintendent of the Government Cotton Plantation at Broach, India, is of sufficient importance to be given in full, as follows:

> The inclosed is an insect which was very destructive to the American cotton which was sown here (Broach) on light alluvial soil. The egg is deposited in the germen at the time of flowering, and the larva feeds upon the cotton seed until the pod is about to burst, a little previous to which time it has opened a round hole in the side of the pod for air, and at which to make an exit at its own convenience, dropping on the ground, which it penetrates about an inch, and winds a thin web in which it remains during the aurelia state. Curious enough, the cotton on the black soil was not touched by it. The native cotton is sometimes affected by it.

The significant thing in the paragraph is the statement that the insect was very destructive to the American cotton and that "*native cotton is sometimes affected by it.*" The fact that the American cotton was much more affected than the native varieties is in accord with the general experience with imported plants in relation to native plant pests, and with introduced pests in respect to native plants. The American variety was apparently unresistant in comparison with the native cottons of India which, with little doubt, had been long associated with this pest and which have developed a certain amount of resistance.

The later records of this insect show that it was reported from India on several occasions prior to 1900 or about that period, and those records determined also its occurrence eastward through Burma, Siam, and the Philippines, long prior to what was undoubtedly its original entry into Egypt in 1906–7.

The insect was first noted in Egypt in 1911, and the first severely infested field, one near Alexandria, was noted in the year following (1912). The increase of the damages from this insect in Egypt has been steady since 1912 and this in spite of very laborious and expensive control operations enforced by the Egyptian Government.

The present distribution, therefore, of the pink bollworm is reasonably traceable to spread from Southern Asia in comparatively recent years. The possible exception is German East Africa, and even there the natural explanation of its occurrence is its recent introduction with cotton imported from India, although there is the possibility, already noted, that the natural range of the insect may have included Central Africa and that the African infestation may therefore have come from such native stock.

PRESENT RANGE.

With the exception of two infestations in Texas, which it is hoped will be stamped out, the known range of the pink bollworm is as follows:

East Africa, West Africa, Egypt, Nigeria, Sudan, Zanzibar, India (very generally), Bengal, Ceylon, Burma, Straits Settlements, China, Philippines (Luzon), Hawaii, Brazil, and Mexico. There is also a record from Japan, although this may be erroneous. At any rate it is not confirmed by Prof. Kuwana, government entomologist, according to a statement published by Fullaway (5). The introduction of the pink bollworm into Brazil and Mexico is very recent, and the available records show very clearly how it was accomplished. As these are of special interest at the present time, the particulars will be given.

The information from Brazil comes through Mr. Edward C. Green, superintendent of the Cotton Department of the Ministry of Agricul-

ture, who has published a very full statement on the subject (8). During 1913 Mr. Green made a trip of inspection through the greater portion of the cotton-producing area in Brazil. Special attention was paid to the seed, not only in the fields but in the ginneries, and no infestation was found. In 1916, however, another trip showed that the pink bollworm was present over wide areas in the States of Parahyba, Rio Grande del Norte, and Ceara. It seems that in the years 1911, 1912, and 1913, the Government of Brazil imported nine tons of Egyptian cotton seed. This seed was not fumigated as it was not suspected that any injurious insect was likely to be carried by it. A test for germination showed 89 per cent viable. It is altogether likely that a percentage of the unviable seeds were those attacked by the pink bollworm. All of this seed was sent to agricultural inspectors in various States and by them was distributed further throughout the cotton-growing districts.

There can be no doubt that the general establishment of the pink bollworm in Brazil was due to the importation of the Egyptian seed, and that incalculable losses to the country could have been avoided if proper quarantine precautions had been taken.

In Mexico the pink bollworm was introduced in 1911. During that season two importations of Egyptian seed were made. One consisted of 125 sacks and was planted near Monterey; the other, of 6 tons, and this was planted in the vicinity of San Pedro in the Laguna. From what is known of the abundance of the pink bollworm in Egypt in 1911 it is probable that both shipments of seed were infested and that both of them contributed to the present infestation in Mexico. It is true that cotton culture has not been continued in the vicinity of Monterey, but the crop of Egyptian cotton produced there in 1911 attracted considerable attention and much of the seed was shipped to the Laguna.

The work of determining the spread of the pink bollworm in Mexico was greatly facilitated by the cooperation of the Mexican Government. The Minister de Fomento, Sr. Pastor Rouaix, Sr. José Duvallon, Director de Agricultura, and Prof. Julio Requelme Inda of his department, showed the greatest interest in the matter as soon as the presence of the pink bollworm in Mexico was known. Sr. Duvallon dispatched a special representative, Sr. Alfonso Madariaga, to Northern Mexico, where he spent some months in making examinations in the Laguna. His findings corroborated in every way the discoveries made by Mr. Busck.

Very recently specimens of the pink bollworm have been received from China. They were collected by Mr. H. H. Jobson, who at the present writing (May, 1918) has just returned from China. Mr. Jobson's notes are as follows:

The collection which I have was secured from the seed room of one of the ginneries in Shanghai and from the fields at Tungchow, about 12 hours' ride by boat up the river from Shanghai. The infestation is more or less general throughout China; however, there may be some small areas where it is not present. A majority of the cotton grown within a radius of 100 miles of Shanghai is shipped into that port before being ginned, and from evidences found at the ginning establishments there is no doubt but what all those regions are infested. In fact, the larvæ are so numerous that by going into the seed room of the gins a person may secure any number of them within a very short time, as they may be seen crawling around over the seed and on the walls.

PRESENT DISTRIBUTION IN MEXICO.

As far as absolutely definite evidence shows, the pink bollworm is confined to three localities in Mexico, one of which is the Laguna district, a valley isolated by mountain ranges about 200 miles from the Texas border. The Laguna, in which the bulk of the total Mexican crop is produced, consists of about 1,200 square miles of land. Mr. August Busck, on a trip to Mexico in the early part of 1917, obtained samples of cotton seed from 40 of the estates in that region. Thirty of these samples were found to be infested and later records indicate infestation on ranches from which no insects in the seeds were received. In short it is evident that through the shipment of cotton seed from one part of the Laguna to another and possibly through the flight of the insect, the pink bollworm has become generally established there. Although the distribution of the pest is naturally irregular at the present time, it is certain that it will become uniform in the course of a few years, and that most energetic steps must be taken by the planters to control or eradicate the insect. Other localities known to be infested in Mexico are Allende, about 40 miles south of Eagle Pass, and the Trevino ranch, immediately opposite Del Rio. In both cases the infestations were the result of the receipt of seed from the Laguna.

NATURE AND AMOUNT OF DAMAGE.

The pink bollworm affects cotton production in several ways. In the first place it destroys a certain number of bolls or portions of bolls, in which case the lint produced is short and kinky (fig. 1). The injury, however, does not end with the reduction in the yield of lint. The crop of seed is correspondingly reduced, and what is obtained is of light weight and poor grade. In the crushing of Egyptian seed in England it was found that the oil content was lower than normal by about 20 per cent, and that the oil actually secured was of dark color and comparatively low value. The work of the insect is also of importance in connection with seed for plant-

ing. The percentage of germination is naturally low and much larger quantities must be planted to secure a stand.

It is evident from what has been said that the pink bollworm must be of interest to all classes of persons concerned in the cotton trade as well as to those engaged more especially in the cultivation of the crop and the utilization of the seed.

The most accurate information concerning the damage by the pink bollworm is in a recent paper by L. H. Gough (7). This investigator conducted studies in lower and middle Egypt to determine the number of bolls attacked by the pink bollworm. The samples consisted each of 100 green bolls taken at random in fields in various localities. These samples were sent to Cairo where they were given a very careful examination. The total number of bolls examined in

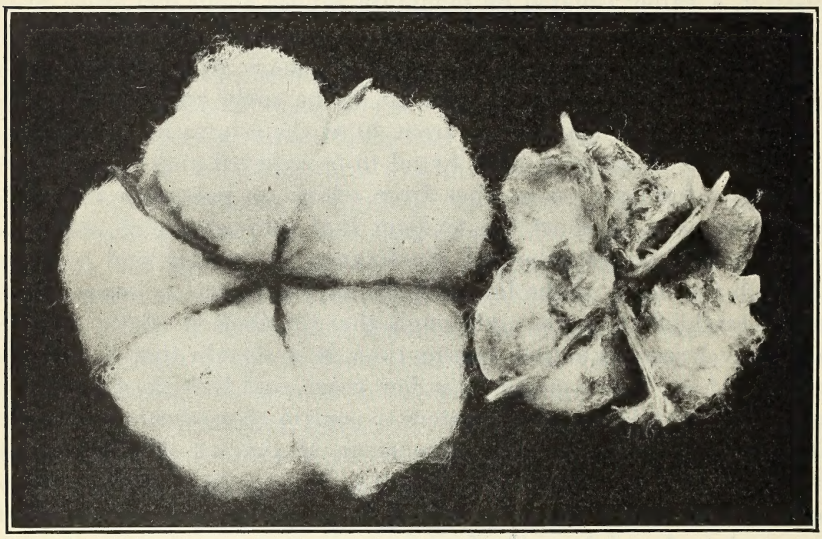

FIG. 1.—At left, normal cotton boll; at right, boll injured by the pink bollworm.

this work was 106,400, and the examinations were continued from July to November. The following are the results of this investigation:

Percentage infested during July, less than 10.
Percentage infested during August, from 10 to 25.
Percentage infested during September, from 25 to 75.
Percentage infested during October, from 75 to 89.

These figures show in a very striking manner the great damage of which the pink bollworm is capable. They may be taken as a fair indication of the injury which would be done in the United States, as the seasonal conditions here are similar to those in Egypt. In short they show that approximately 25 per cent of August bolls and 50 per cent of the September bolls would be destroyed or rendered

practically valueless by the insect. They further illustrate the rapid increase of infestation of green bolls with the advance of the season, and indicate the possibility of a high reduction of yield, particularly in all late-maturing cottons where the second and third pickings are of importance. Fortunately for Egypt, one of the principal varieties of cotton grown there, the Sakellarides, matures its crop early and yields most of its cotton with the first picking. In spite of this favorable condition, however, and of expensive control operations enforced by the Government, a very conservative estimate by experts indicates a loss of at least 17 per cent to the Egyptian crop due to this insect. In the Hawaiian Islands the pink bollworm has prevented the development of the cotton industry which at one time showed considerable promise. With relation to German East Africa a statement is made that the pest normally becomes so abundant in two or three years after its introduction in the field as to necessitate abandoning the crop (11).

In Brazil the Minister of Agriculture recently has collected data for an estimate of the damage to the cotton crop caused by the pink bollworm by addressing communications to the governors of the principal cotton-producing states of the Republic. The following is a summary of the results of this investigation:

Losses on account of ravages of pink bollworm in Brazil: Crop of 1917.

Brazilian state.	American currency.
Maranhac	$ 750,000
Piauhy	500,000
Ceara	10,000,000
Rio Grande do Norte	2,500,000
Parahyba	5,925,000
Pernambuco	5,750,000
Alagoas	1,575,000

The loss referred to in the table ran from 30 per cent of the crop in the State of Alagoas to two-thirds of the crop, or 30,000 metric tons, in the State of Ceara.

In Mexico the actual injury caused by the pink bollworm was investigated by the Joint Commission representing the Mexican and American commissions. This commission visited many plantations in the Laguna in 1917. It reported that the loss to the crop of 1917 chargeable to the pink bollworm was not less than 30 per cent. Mr. August Busck, who was a member of the commission, personally estimated losses ranging from 30 to 50 per cent, with individual fields showing even higher losses.

DESCRIPTION AND LIFE HISTORY.

The pink bollworm has four stages, namely, egg, larva, pupa, and adult or moth. The moth (fig. 2) resembles somewhat the common

clothes moth of this country. From tip to tip of the extended wings it measures from three-fifths to four-fifths of an inch. It is of a dark-brown color, the forewings ending in a rather sharp point. The hindwings are somewhat broader than the forewings and end in an even sharper point. The eggs are very small objects, somewhat oval, about one-twenty-fifth of an inch long and one-fiftieth of an inch broad. The surface is white and finely wrinkled. The larva (fig. 3) when first hatched is glassy white with light-brown anterior markings. It grows rapidly, and when mature measures nearly a half inch in length. It is cylindrical, white, with the dorsal side strongly colored with pink.

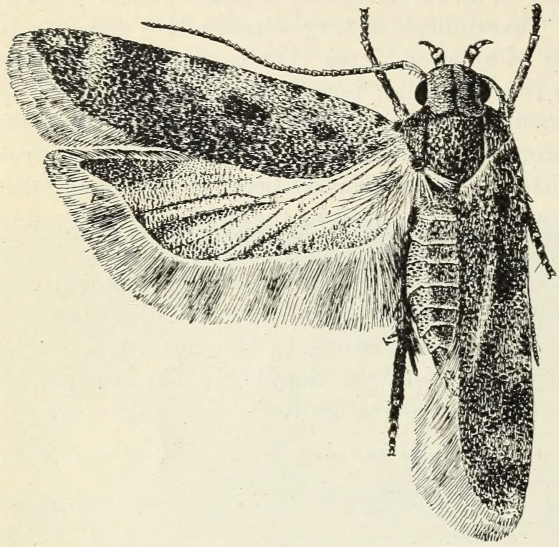

FIG. 2.—The pink bollworm (*Pectinophora gossypiella*): Adult. Much enlarged. (Busck.)

The pupa (fig. 4) is about two-fifths of an inch in length, reddish brown, the posterior end pointed and ending in a hooklike process.

There are several insects found in bolls of cotton in the United States which may be mistaken for the pink bollworm. One of these is the so-called pink cornworm or scavenger bollworm (*Pyroderces rileyi* Walsingham), which frequently is found in decaying bolls, especially those which have been injured by disease. It has not been known to attack healthy bolls. It does not normally make its way into the seed, and this fact will help in distinguishing it from the pink bollworm. Another insect which may be mistaken for the pink bollworm is the common bollworm of cotton (*Chloridea obsoleta* Fabricius). This is the same insect that feeds on corn and is known in some parts of the country as the corn earworm. It bores holes through the carpels of the bolls, feeds for a short time, and then proceeds to another

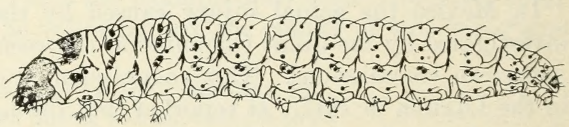

FIG. 3.—The pink bollworm: Outline drawing of larva, showing structure. Much enlarged. (Busck.)

boll. In the early stages it sometimes assumes a somewhat pinkish color. It may be distinguished from the pink bollworm by its habits, especially by the fact that it does not feed altogether in the interior of the bolls and that it is not found within the seeds. When full grown it is much larger than the pink bollworm, measuring about 2 inches in length.

The insect most likely to be mistaken for the pink bollworm is the boll weevil. Although the boll weevil is sometimes found in seeds, it generally is found feeding within the interior of the boll. It discolors the fiber considerably, and this causes the interior of the boll to assume a more or less decayed appearance, quite unlike the appearance of bolls infested by the pink bollworm, in which decay generally does not occur. *This so-called cleanliness of the work of the pink bollworm is one of the most useful characteristics in differentiation.*

The accompanying illustrations will assist the reader in deciding whether the work in question is that of the pink bollworm or some other insect found in cotton bolls.

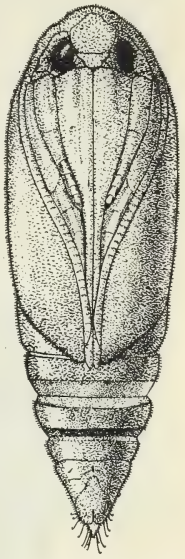

FIG. 4.—The pink bollworm: Pupa. Much enlarged. (Busck.)

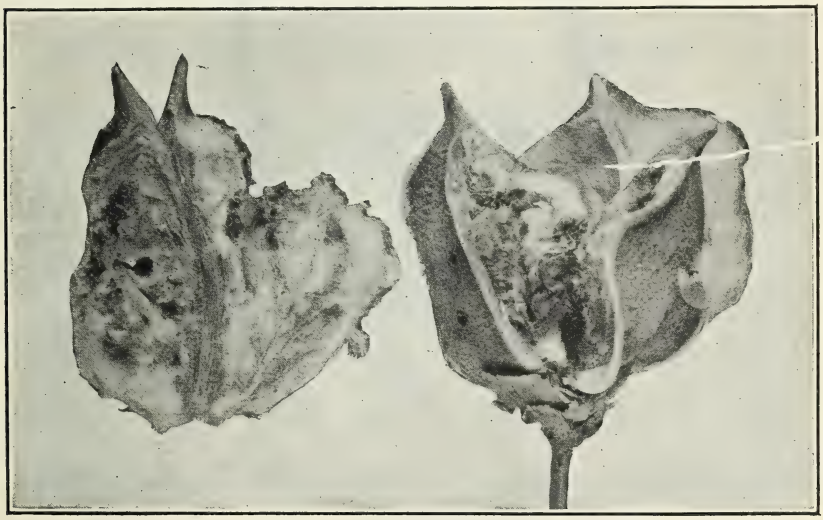

FIG. 5.—Exit holes of pink bollworms in cotton bolls.

Figure 5 shows on the left the appearance of the interior of an injured boll, and on the right the characteristic small circular opening made by the larva for the purpose of allowing the adult to emerge.

Figure 6 shows on the left the characteristic opening made by the ordinary bollworm (*Chloridea obsoleta*). It is of large size and surrounded by a raised margin. The exit holes of the pink bollworm, on the left, are much smaller, more regular, and without raised margins.

Figure 7 shows the appearance of locks of cotton, exhibiting typical injury by the pink bollworm.

Figure 8 shows individual seeds infested by the pink bollworm. In the lower line are the "double seeds." These are frequently

FIG. 6.—Two bolls showing distinction between exit holes of the ordinary bollworm or corn earworm (*Chloridea obsoleta*) and those of the pink bollworm (*Pectinophora gossypiella*). The large hole in the boll to the left was made by the ordinary bollworm and the two small ones in the boll to the right are typical of the pink bollworm.

found as the result of the webbing together of two seeds by larvæ of the later stages in order to obtain more room for pupation.

Figures 9 and 10 illustrate the pink bollworm in a burr and the typical opening made by this insect when it makes its way from one lock to another.

Although these descriptions may help in enabling any one to determine whether the pink bollworm is present in a cotton field, it will always be best to send any specimens to an entomologist without delay for authoritative determination. It is extremely important that any possible infestation by this insect be brought to attention

at the earliest possible date, that prompt eradicative measures may be taken.

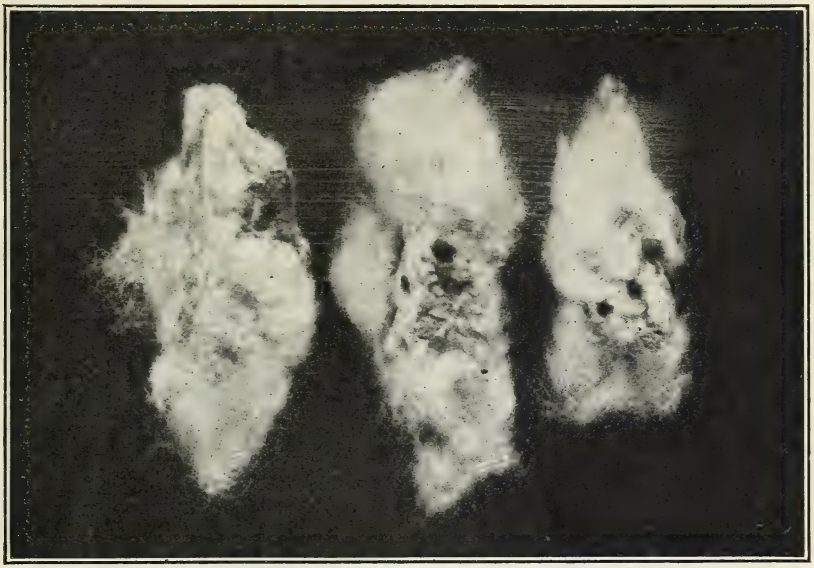

FIG. 7.—Cotton locks showing typical injury by the pink bollworm (*Pectinophora gossypiella*).

Under the authority of the Federal Horticultural Board, Mr. August Busck spent a number of months in the Hawaiian Islands in 1905 studying the life history and habits of the pink bollworm. His

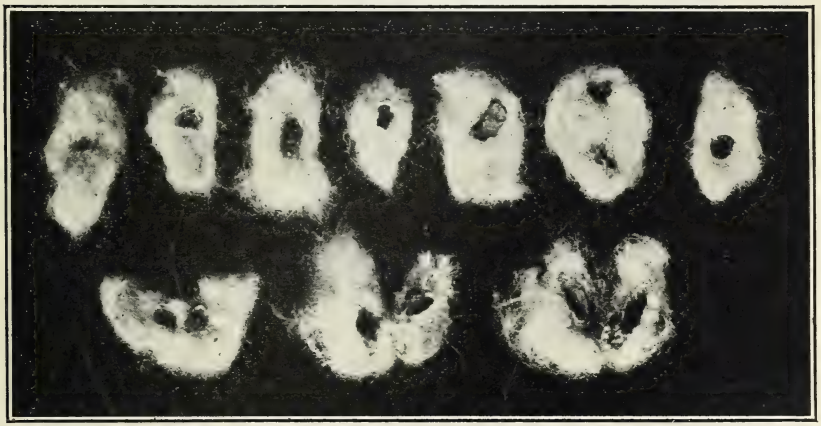

FIG. 8.—Cotton seed containing pink bollworms, opened to show the cells. Both the single and double seeded cells are shown, the double-seeded ones being broken apart.

paper (2) on the subject is by far the most complete of any which has been published. The following statements regarding the life history and habits of the pest are based upon Mr. Busck's paper:

The eggs are laid singly or in small groups on the green bolls or in the flowers. Generally the eggs are to be found near the points of the green bolls in the sutures marking the locks. As many as 4 eggs may be found in this situation and altogether as many as 20 eggs have been found on a single boll. It is estimated that a female will deposit in the neighborhood of 100 eggs. These hatch in from 4 to 12 days.

The larva, immediately on hatching, bores its way into the boll. The infested bolls sometimes become recognizable by a reddish or blackened discoloration which follows attack. Mr. Busck finds, however, that the only conclusive exterior evidence of infestation is the eggshell at the entrance hole or the larva itself within the boll.

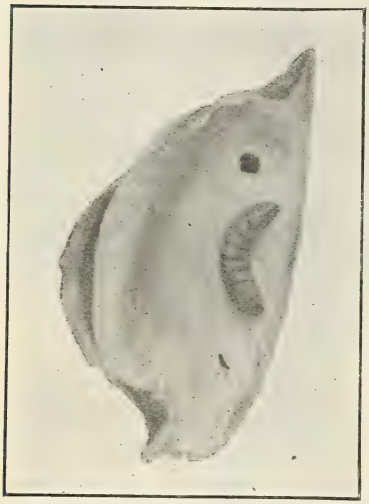

FIG. 9.—Pink bollworm on carpel of cotton boll, which shows also typical hole made by worm while traveling from one lock to the next.

The food of the larva is the seed within the boll. It devours one and generally proceeds to the next above. Ordinarily a single larva does not make its way outside of the lock which it first invades, but occasionally the adjoining lock may be entered. It is to be noted that the larva restricts itself to the interior of the boll and never makes its way to the outside for the purpose of reaching another boll. When the larva reaches full growth it often protects itself by webbing two seeds together, the attachment being made to openings brought into contact by the insect. These "double seeds" are characteristic of the work of the insect. Usually they are not destroyed in the process of ginning, and they furnish the best means of determining quickly whether any lot of seeds is infested.

During the summer the larva stage occupies from 20 to 30 days. Later in the season this stage may be more or less indefinitely prolonged. Gough (6), in Egypt, found that larvæ would remain in a quiescent condition for over two years. Mr. Busck caused infested seeds to be placed in small bales of cotton in Honolulu. Examinations made up to 18 months after the time of baling continued to reveal the presence of live larvæ. It is thus evident that the larva stage may be prolonged over at least two growing seasons. It is this feature in the life history of the pest which has facilitated its carriage to many remote quarters of the earth.

After a variable time, as has been indicated, the larva transforms into a pupa or chrysalis. This stage lasts from 10 to 20 days and then the moth emerges. The life of the moth is rather short. Under favorable conditions Mr. Busck succeeded in keeping some specimens alive for 32 days, but under the same conditions the great majority of the insects died in from 14 to 20 days.

The moth is seldom seen in nature. Its habit is to hide during the day under stones or brush. The normal time of flight is from 6.30 to 8 p. m.[1] Although apparently capable of prolonged flight, they prefer to go no farther than the first cotton field. The moth is so quiet in its habits and so easily overlooked that many may occur

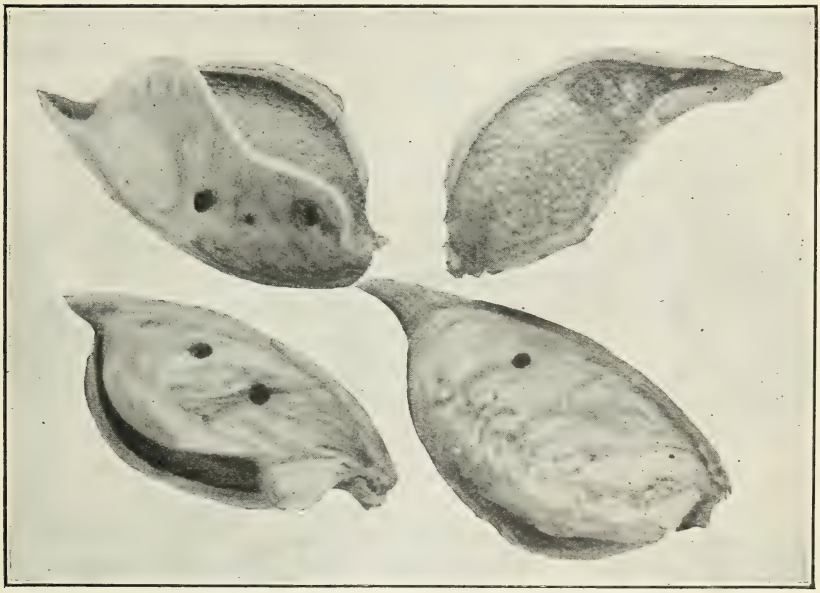

FIG. 10.—Typical holes made by pink bollworms through cotton-boll carpels.

unnoticed in the field. In fact Mr. Busck states that frequently he walked through cotton fields in the Hawaiian Islands where the moths had been emerging daily for an indefinite time, and where many thousands must have been present, without seeing a single one.

Statements to the effect that the pink bollworm is attracted to lights have appeared in the literature. Mr. Busck paid particular attention to this point and demonstrated that in Hawaii lights have no attraction whatever for the insect. In fact, the moths were clearly repelled by light. In Egypt experiments have shown some degree of attraction to light but not enough to form the basis for control measures.

[1] Standard time.

The question of the food plants of the pink bollworm is one which has been discussed at considerable length. There are statements in the literature to the effect that the species feeds on pomegranates in Egypt, on milo in Hawaii, and in Egypt and India on teel, okra, and hollyhock. The record relating to pomegranates has been withdrawn by Mr. H. A. Ballou, who has recently published a statement to the effect that it was an error. With reference to milo Dr. D. T. Fullaway has made a statement that the record was from a single specimen from a fallen fruit and that this specimen may well have been a stray larva which crawled into a cracked milo fruit for pupation.

Mr. Busck's observations in the Hawaiian Islands did not reveal any food plants other than species of the genus Gossypium, that is cottons. More recently, however, a statement has been published to the effect that the insect has been reared from a closely related plant belonging to the genus Hibiscadelphus.

The subject of the food plants of the pink bollworm in Mexico and Texas is now receiving very special attention. The extent to which okra, hollyhocks, and various wild malvaceous plants will have to be considered as host plants for the insect in noncotton zones depends upon these investigations, which are being prosecuted thoroughly and with the utmost possible dispatch.

As far as observed, the insect has no preference for cultivated varieties of cotton. The perennial or Caravonica, Chinese, Sea Island, and American Upland varieties growing in Hawaii were attacked to the same extent. Similar observations have been made in Egypt and India.

NATURAL ENEMIES.

The pink bollworm has a number of insect enemies wherever it occurs. In the Hawaiian Islands Busck found at least six species attacking it. Other species have been recorded from Egypt, Brazil, and India.

By far the most important enemy of the pink bollworm is a small mite known as *Pediculoides ventricosus* Newport. This is a common enemy of insects and occurs throughout the world. It seems to have increased to a very considerable extent in Egypt, but it does not appear that it is likely to be sufficiently abundant at any time to serve as an important agency in controlling the pink bollworm. Neither does it appear from the available records that any insect or mite enemies of the pest are likely to be of any practical importance in controlling it.

It is interesting to note that the mite to which reference has been made also attacks human beings. In 1914 large quantities of

Egyptian cotton seed were shipped to London. The laborers employed in handling this seed became affected by a rash of the skin caused by the punctures of the mite. The irritation was severe and resulted in a strike for higher wages. Recently the writer has learned from Mr. E. C. Green that in Brazil, since the establishment of the pink bollworm there, children who play about seed houses soon become affected by a dermatitis which probably is the same as that which has been found to follow the attack of the mite in other parts of the world.

PRECAUTIONS TAKEN TO PREVENT THE INTRODUCTION OF THE PINK BOLLWORM INTO THE UNITED STATES.

Prior to 1913 a considerable number of planters and others interested in the production of long-staple cottons in the United States caused small importations of Egyptian seed to be made. They were planted in many of the southern States, but did not result, for various reasons, in the establishment of the culture of Egyptian cottons. The Department of Agriculture also made special importations. In 1902 a considerable quantity of seed was brought from Egypt and small experimental plantings were made at Pierce and San Antonio, Tex., and at various other points in the Southwest. That the establishment of the pest did not follow any of these importations is due to the recent introduction of the insect into Egypt.

With the approval of the plant quarantine act on August 20, 1912, the Department of Agriculture for the first time obtained authority to regulate the importations of plants and plant products from foreign countries and to take the steps necessary to prevent the introduction of injurious insects and plant diseases by such importations. The pink bollworm was one of the first insects to be considered after the plant quarantine act went into operation. Its foreign status and its menace to American cotton was first brought to the attention of the Federal Horticultural Board in April, 1913, and on May 20 of that year a formal hearing was called at Washington to consider the advisability of prohibiting the importation of cotton seed from all foreign countries. No special opposition was encountered and a quarantine was promulgated on May 28, 1913, to take effect on July 1 of that year. This quarantine forbade the importation into the United States of cotton seed of all species and varieties, and cottonseed hulls from any foreign locality and country excepting the Imperial Valley in the State of Lower California in Mexico. The importation from this region in Mexico was covered by regulations. The importance of this action was shown in May, 1913, by the receipt in Arizona of a shipment of 500 pounds of Egyptian seed

which was found to have an infestation by the pink bollworm of about 20 per cent. Thanks to the quarantine law in Arizona and the activity of Dr. A. W. Morrill, the State entomologist, the whole shipment was destroyed by fire.

A little later (Aug. 18, 1913), on the recommendation of the experts of the Bureaus of Entomology and Plant Industry of this department, this quarantine was amended in such manner as to provide, under regulation, for the entry, for milling only, of cotton seed from the States of Nuevo Leon and Tamaulipas, Mexico. A still later amendment permitted the introduction of seed from other of the northern states of Mexico.

The reasons advanced for allowing such entry of Mexican cotton seed were that no insects which were not found in the United States were known to occur there, and that the culture of cotton is more or less continuous with that in the United States. The absence of any cotton pests in the Republic of Mexico which did not occur in the United States at that time had been established by field inspections by several of the entomologists of the department.

To protect the United States from the possible entry of the pink bollworm from the Territory of Hawaii, a domestic quarantine was promulgated June 24, 1913, prohibiting the importation of cotton seed and cottonseed hulls from this territory.

It was thought that the United States was sufficiently safeguarded against the pink bollworm by the quarantines against cotton seed as such, but it soon came to notice that considerable quantities of seed were coming to the United States in bales of lint. A careful examination of picker waste from a large number of bales of Egyptian cotton was made. It was found that considerable numbers of seeds passed around the rollers in the gins and some between the roller and the knife through small openings due to wear. The waste from 37 bales which was examined showed sound seeds, some of them infested, varying from 27 to 600 per bale. The average per bale was 215. The variation in the different bales depended upon the grade of the cotton, the lower grades having many more seeds than the better ones. It was estimated on the basis of the examination of waste from the 37 bales that over 16,000 live larvæ of the pink bollworm were being brought to the United States each year, of which several hundred went to the mills in the cotton belt.

It thus became evident that a quarantine which did not take into consideration the seeds in bales of lint was inadequate. Consequently in May, 1914, a public hearing was held to discuss various means of protection. The different proposals made were that foreign cotton be excluded altogether from the United States; that it be admitted only under a guaranty that all seeds had been eliminated, or

that it had been disinfected; that it be allowed to proceed only to mills outside of the cotton belt; and that it be sent to southern cotton mills only after a period of storage of 18 months or more in northern localities. At the public hearing, and subsequently through conferences with members of the cotton trade and representatives of manufacturing associations whose assistance was very valuable to the department, it became evident that there were insuperable obstacles in the way of any of the plans mentioned. It therefore became necessary to make an exhaustive study of the possibility of destroying any infestation which might be found in the bales of lint. The use of cold was found to be impracticable. The use of heat was also impracticable on account of the time necessary to penetrate the highly compressed bales of Egyptian cotton and on account of the increased danger from fires when bales which had been heated were opened in the mills.

About this time Mr. E. R. Sasscer, of the Federal Horticultural Board, and Dr. Lon A. Hawkins, of the Bureau of Plant Industry, had been conducting some experiments in the destruction of insects in various plant products by fumigation in a vacuum. It was found that the killing power of hydrocyanic-acid gas was increased enormously in vacuum and it thus became possible to reach certain classes of insects which heretofore had been uncontrollable. It therefore seemed possible that the vacuum process might be utilized in the fumigation of bales of cotton without necessitating their opening. A small experimental plant was established by the board at Washington and a long and what turned out to be a most interesting series of experiments was begun by Mr. Sasscer.

While this investigation was in progress an order regulating the entry of all imported lint cotton was promulgated by the Secretary of Agriculture April 27, 1915, effective July 1, 1915, and a domestic quarantine regulating the movement of cotton lint from the Territory of Hawaii to the mainland was promulgated June 11, 1915, effective on and after July 1, 1915. Under this order and quarantine, tentative regulations were issued governing and restricting the entry of foreign cotton and also providing for the screening of all rooms or buildings in which foreign cotton was kept and the daily burning of all grades of mill waste in which seeds of such cotton might be found. A corps of inspectors was employed and frequent examinations were made at the mills where foreign cotton was used to insure the faithful following of regulations. In general sympathetic coooperation was obtained. This was especially noticeable in the case of southern mills, the owners and managers of which seemed to realize the danger of introducing the pink boll-

worm and complied with the orders and regulations of the Federal Horticultural Board in the most hearty and public-spirited manner.

In the experiments with vacuum fumigation of lint cotton conducted by Mr. Sasscer, under the direction and with the advice of the Federal Horticultural Board, tests were made with variations in the dosage of cyanid, the degree of vacuum, the length of exposure, the temperature, and also in the depth of penetration. Steel tubes pointed at one end were provided. These had perforations near the point and were sealed in such a manner as to be perfectly airtight at the other end. Insects were placed within them, and the tubes were then driven into the bales. After the experiment was performed the insects were removed for examination. In this way the exact effect of the fumigation under all varying conditions at different depths within the bales could be determined. At the same time chemical tests were made by the Bureau of Chemistry of this department to run parallel with the tests with insects. These chemical tests confirmed the rapid penetration of the gas.

As the result of a suggestion made following a conference of a committee of cotton manufacturers with the Federal Horticultural Board, the then Office of Markets and Rural Organization of this department conducted a series of manufacturing tests with cotton which had been fumigated with hydrocyanic-acid gas to determine whether the fumigation by this agent would cause any injury to cotton fibers. The results of these tests indicate that such fumigation of cotton did not cause any deterioration of the cotton, either as to percentage of waste, spinning qualities, tensile strength, or bleaching, dyeing, or mercerizing properties of the cotton (3).

In the first series of experiments various insects more or less related to the pink bollworm, but which are native to the United States, were used. After the preliminary work was done and the probable requirements for destroying any insect in the bales of lint were determined, it was decided to add a series of experiments with the pink bollworm itself. For this purpose, under extreme caution to avoid escape, a number of insects were brought from the Hawaiian Islands. The results in all essential respects were similar to those that followed in the case of the insects treated previously.

As the result of all of this work, which taxed the ingenuity of the investigators engaged in it, it was found feasible on a commercial scale to fumigate densely compressed bales of cotton and kill any insect which might be inside.

On March 10, 1916, the fumigation of all bales of foreign cotton arriving at the United States was required as a condition of entry. Advance notice had been given to the importers and others concerned. In spite of considerable difficulties in obtaining materials and in working out mechanical problems, large plants were erected

in a remarkably short time and became available for use on the date mentioned. Two of these plants were erected in Boston and one at Oakland, Cal. A little later additional plants were erected at New York City and Newark, N. J., and two plants are now available in Seattle, Wash. These establishments have a capacity sufficient to handle all of the imported cotton without any special delay. The larger plants have a capacity of upward of 1,000 bales per day.

The procedure to be followed in the fumigation of foreign cotton is given in an order of the Federal Horticultural Board (12). The kind of cyanid and sulphuric acid is specified. The rate is 6 ounces of sodium cyanid per 100 cubic feet. The cotton to be fumigated is placed in the fumigating chambers, the doors to these chambers are closed, and the air is exhausted until the vacuum gauge registers 25 inches. At this stage the gas is generated in a retort connected with the large chamber. The valve of the connecting pipe is opened; after the expiration of 15 minutes air is allowed to pass through the generator for 5 minutes for the purpose of removing any gas which may be present. The air valve on the fumigating chamber is then opened and the air allowed to rush in until the gauge registers 5 inches. The cotton then remains in the chamber for 1 hour and 40 minutes, making the total process of fumigation 2 hours. After the completion of the exposure, to remove the gas the pumps are run again and a vacuum of 25 inches established. At this stage the valves are opened and the pumps kept running for some time to complete the washing out of the gas from the bales. The pumps are then stopped and the doors of the chamber opened so that the cotton can be removed and another lot put in.

On December 27, 1915, Mr. R. I. Smith, the inspector of the board at Boston, Mass., called the attention of the board to the fact that a considerable amount of cotton waste was being imported. Some of this waste was found to contain more than twenty times as much seed as a bale of ordinary cotton. On this account the definition of the term "cotton" in the regulations was changed to include all grades of cotton waste except those resulting from processes of manufacture which render it mechanically impossible that seeds may be contained. These are the grades of waste resulting from the carding machines and subsequent processes in the manufacture of cotton. The requirement of fumigation of cotton waste went into effect on February 16, 1916.

On April 11, 1916, the collector of customs at Norfolk, Va., telegraphed the board that some 189 tons of cotton seed from Lagos, West Africa, constituted a portion of the cargo of the British steamship *Appam*, brought to Newport News as a German prize of war. In cooperation with the Office of Markets the board took immediate steps

to dispose of this seed, which was found to be infested by the pink bollworm. A provisional sale had been made by the admiralty board to the proprietor of an oil mill in South Carolina. This was set aside as soon as the danger of introducing the pink bollworm was explained. After considering a number of methods of disposing of this seed, it was finally decided to have it treated with sulphuric acid and thus made available as a fertilizer. Through the cooperation of one of the largest manufacturers of fertilizers this was done with the utmost dispatch. The entire lot of 4,000 bags of seed was placed in sulphuric-acid vats within four days from the time the presence of the seed at Newport News became known to the department. As an additional precaution the two holds of the *Appam* which contained the seed were fumigated with a heavy dose of cyanid, and the docks, lighters, and trucks, as well as floors and platforms, were thoroughly cleaned of any scattered seeds.

To guard against the possibility that the pink bollworm had escaped prior to the treatment which has been described, repeated inspections were later made of the cotton fields near Newport News, which are at a distance of about 10 miles. No traces of infestation have been found, and it now seems certain that the establishment of the insect from this seed was prevented.

The chief inspector of the Board in New York City, Mr. Harry B. Shaw, reported in February, 1916, that there appeared to be considerable risk of introduction of the pink bollworm or other cotton insects with old burlaps which had been used for coverings of cotton and to which, as a rule, considerable cotton and occasional cotton seeds remain attached. Such burlaps are imported in large quantities for paper manufacture and other uses, and an investigation which was made of such imports in New York and Boston fully confirmed the risk of the introduction of cotton and cotton seed with such materials. An amendment was therefore added to the rules and regulations governing the importation of cotton into the United States, effective August 1, 1916, providing for the inspection and, where necessary, disinfection of all burlaps or other fabrics offered for import which had been used for covering cotton and to which cotton was adhering.

The possibility of entry of uncrushed seeds containing living pink bollworms or other cotton insects with cottonseed products, such as cake and meal, became evident after careful examination of such imports, and to safeguard their entry an order restricting the admission of cottonseed cake, meal, and all other cottonseed products, except oil, from all foreign countries was promulgated June 23, 1917, and regulations under this order were issued June 29, 1917, effective on and after July 16, 1917.

DISCOVERY IN MEXICO.

Earlier in this bulletin attention has been directed to the fact that when the quarantine against foreign cotton seed was placed in operation the State of Lower California, Mexico, was not included, and that subsequently cotton seed was permitted entry, for milling purposes only, from certain northern States of Mexico. The reason for this was that several of the entomologists of the department had been in northern Mexico and had found no traces of infestation by any insects other than those which are known to occur in the United States. These explorations were made some years ago, however, and it was still thought desirable to have new examinations made on account of the suspicion that the pink bollworm or some other destructive pest might have been introduced in the meantime. Accordingly arrangements were made in 1916 to dispatch an agent to Mexico. Shortly before the time fixed for his departure the activities of the bandits became so great that the trip had to be postponed indefinitely. If it had not been for these circumstances the presence of the pink bollworm in Mexico would have been known some months before it actually came to the attention of the department.

On November 1, 1916, the department received from a planter in the Laguna, who was then residing in Mexico City, a number of specimens of cotton bolls which had been attacked by insects. The sender was under the impression that the insect was the boll weevil which, though introduced in the Laguna on numerous occasions, had never been able to maintain itself on account of climatic conditions. Several of the bolls were found to be infested by the boll weevil, but others showed the presence of the pink bollworm. The determination was first made by Dr. W. D. Pierce and confirmed by Mr. August Busck and other specialists of the Bureau of Entomology.

On November 3, 1916, the situation was considered by the Federal Horticultural Board, and on November 4 an amendment to the regulations extending the quarantine to cotton seed and cotton from Mexico was issued by the department. An investigation was immediately started to determine the extent of the infestation in Mexico and the number of shipments of cotton seed from that country to the United States. It was soon found that a large amount of Mexican cotton seed had been shipped to mills in Texas during the season of 1916. In previous years no Mexican cotton seed had been shipped to the United States, and it was only the disturbed conditions in Mexico and the unprecedented high price of seed in the United States which caused the seed mentioned to be forwarded to the United States.

It was found that a total of 446 carloads of Mexican seed had entered the United States during 1916 prior to November 4. These car-

loads went to mills at Beaumont, Pearsall, Kaufman, Hearne, San Antonio, Houston, Dallas, Wolfe City, New Braunfels, Grand View, and Alice. The amounts varied from one carload, which went to Wolfe City, to 114 carloads, which went to Beaumont. Ninety-three carloads were shipped to Hearne and 69 to Kaufman, both located in regions where cotton is cultivated on every plantation.

The State authorities in Texas were notified and the Federal Horticultural Board began a campaign to expedite the crushing of the seed and the destruction of any scattered seeds about the premises. The cooperation with the State was through Hon. Fred. Davis, commissioner of agriculture, the entomologist of his department, Mr. E. E. Scholl, and the chief nursery inspector, Mr. E. L. Ayers.

Agents of the Federal department visited the mills which had received the Mexican seed at frequent intervals through the fall and winter. The force was increased by the addition of three men detailed from the Office of Markets of this department. The proprietors of the mills and the State Cottonseed Crushers' Association all assisted very materially in the work, which was done with the utmost possible dispatch and with great thoroughness.

SPECIAL APPROPRIATION FOR THE DEPARTMENT OF AGRICULTURE.

In November, 1916, the department submitted to Congress an estimate for an appropriation of $50,000 to be used, first, in determining the possible presence of the pink bollworm in the vicinity of the mills which received Mexican seed and to stamp out any infestation which might be found; second, to enforce the quarantine against Mexican seed and cotton products which might carry the pink bollworm. This appropriation became available on March 4, 1917.

Under the appropriation the Federal Horticultural Board organized a full field force. It consisted of one set of inspectors to make field examinations to determine whether the pink bollworm could be found, and another to enforce the quarantine regulations at the border ports.

DISCOVERY IN TEXAS.

As the result of the field examinations, to which reference has been made, the first specimen of the pink bollworm in Texas was discovered in Hearne, Tex., on September 10, 1917, by Ivan Schiller, an inspector of the board. This was found in a small field adjoining the oil mill which had received Mexican cotton seed. Later four additonal specimens were found, none of them more than one-fourth of a mile from the mill. On October 5 a specimen was found in a field near the oil mill at Beaumont by inspector H. C. Millender, and on October 25 specimens were taken at Anahuac, in Chambers County, by Mr. H. S. Hensley. The first two of these infestations

were undoubtedly due to the Mexican seed which had been shipped to the United States in 1916. The infestation in Chambers County, however, can not be attributed to such shipments. It was found to extend around Galveston Bay from Smiths Point to the vicinity of Texas City. It was heavier near the Bay and diminished regularly toward the interior. After considerable investigation, in which all possible theories have been investigated, the conclusion has been reached that this infestation was probably due to Mexican bales of cotton which were shipped to Galveston in 1915. During this year several thousand bales of cotton from the Laguna in Mexico reached Galveston by way of El Paso. This cotton was on the docks at Galveston at the time of the hurricane of August, 1915. With several thousand bales of Texas cotton it was washed from the docks and distributed around the shore line, in some cases 75 miles away. Many of these bales were broken open by the force of the water. It is well known that Mexican bales contain large numbers of seeds, and cotton plants were found growing along the high water line during the fall of 1915 and the spring of 1916. This theory, while not altogether satisfactory, is considered by Mr. August Busck, who has paid more attention to the study of the pink bollworm than any other entomologist, to be adequate to explain the known situation at the present time around Galveston Bay.

As soon as the presence of the pink bollworm in Texas was discovered the Federal Horticultural Board, in cooperation with the Department of Agriculture of the State of Texas, undertook active measures to eradicate it. The work consisted at first of scouting to determine the limits of infestation, the destruction of any possible infestation remaining in the fields, and the safeguarding by various means of the cotton produced in the infested fields and in neighboring ones during the season of 1917.

Entomologists were obtained from various sources. Twenty-five were engaged in the scouting work in Hearne, and later about 50 in the work in southeastern Texas. As the result of this work it seems practically certain that the infestation in Hearne was limited to the immediate vicinity of the oil mill. In southeastern Texas infestation was found from the vicinity of Beaumont, in Jefferson County, to Arcola, about 7 miles from the Brazos River. The northernmost point infested was in Liberty County, about 18 miles north of the town of Liberty. This area includes all of Chambers, Galveston, and Jefferson Counties, and portions of Liberty, Harris, Brazoria, and Hardin Counties.

The work of removing any possible infestation from the fields consisted of uprooting or chopping down the plants, the collection by hand of all locks or portions of locks which were found on the ground, and the burning of all the accumulated trash with the use

of kerosene. In this work 1,624 acres of land in the vicinity of Hearne were cleaned, and 7,170 acres in southeastern Texas. The work was not confined to fields in which infestation was actually found, but included fields at a considerable distance beyond the outermost points found infested. It involved the employment of an average of about 500 laborers for the months of November, December, January, and February, and a portion of March. In many cases the laborers were assembled in camps and housed and provisioned by the department. In other cases, where the work was in the vicinity of towns, it was possible to employ local labor. The safeguarding of cotton products produced in the infested areas in 1917 consisted of the milling of the seed under supervision at certain mills selected because their construction would enable the work to be done with practically no danger of disseminating the pest. The baled cotton, so far as possible, was caused to be exported or shipped directly to northern mills.

COTTON-FREE ZONES.

In 1917 the Legislature of Texas passed an act intended to give authority to prevent the establishment of the pink bollworm in the State. Under this act authority was granted to quarantine the districts in which the insect might be found, and to establish zones in which the planting of cotton might be prohibited. Under this authority on January 21, 1918, the governor of Texas quarantined the Hearne district as well as the territory found infested in southeastern Texas. In the case of Hearne the quarantined area included a territory within a radius of 3 miles from the mill. In the case of southeastern Texas the quarantined area included a safety zone on the outermost points infested approximately 10 miles in width.

On February 25, 1918, following the recommendation of Hon. Fred W. Davis, commissioner of agriculture, the governor of Texas issued a proclamation prohibiting the planting of cotton in the quarantined areas.

The finding of infestation by the pink bollworm in Mexico not far from Del Rio in the spring of 1918 made it necessary to place in operation another section of the Texas pink bollworm act. As a consequence a third noncotton zone was provided to include McKinney, Maverick, and Valverde Counties.

SPECIAL REGULATION AT MEXICAN BORDER.

The risk of direct entry of the pink bollworm from Mexico by flight or by accidental carriage necessitated the provision in the regulations governing the entry from Mexico of cottonseed cake, meal, or other cottonseed products, including oil, that permits for such entry should be issued only for the products named produced in

mills located in the Laguna district of Mexico. The object of this proviso with relation to Mexico is to deter the erection of mills near the border of the United States with the consequent risk of escape of insects from seed brought for crushing to such mills near the border.

In this connection it may be noted that active steps toward the control of the pink bollworm have been undertaken in Mexico. A recommendation was made to the Mexican Government by a joint commission, one of the members of which is Mr. August Busck, of the United States Department of Agriculture, that the cultivation of cotton in infested regions be prohibited for a period of three years. It has not been possible up to the present time for the Mexican Government to place this recommendation in operation, but it has issued two decrees looking toward the control of the insect. One of these is a quarantine against the main infested territory with a provision for a safety zone of considerable width. The other provides for the fumigation of all cottonseed produced, whether intended for crushing or planting.

PRESENT WORK OF THE DEPARTMENT OF AGRICULTURE.

To meet the menace of the pink bollworm the activities of the department through the Federal Horticultural Board now include:

(1) The exclusion from the United States of cotton seed from all foreign countries except the Imperial Valley of Lower California, Mexico, and its exclusion also from Hawaii;

(2) Regulating and safeguarding the entry of cottonseed products from all foreign countries and from Hawaii;

(3) Regulation of entry and disinfection of all imported cotton and cotton waste, and also burlaps which have been used as wrappings of foreign cotton, including such material from Hawaii;

(4) Survey, eradication, and control work in Texas in cooperation with the State authorities;

(5) Regulation of rail and other traffic with Mexico;

(6) Determination of distribution in Mexico and cooperation in control measures with the Mexican Government or local Mexican authorities; and

(7) Investigation in Mexico of the life history and habits of the pink bollworm as a basis for control measures.

Detailed information as to these activities and the quarantine and other restricting orders and regulations in relation to cotton and cotton products are given in the monthly numbers of the Service and Regulatory Announcements of the Federal Horticultural Board (13).

In general the work in Texas consists of cooperation with the State of Texas in maintaining the cotton-free zones and safeguard-

ing the products produced therein in 1917, in extensive scouting to determine at the earliest moment the occurrence of the insect in any point in Texas or elsewhere, and in eradicative work.

The work at the Texas border ports consists of the regulation of the traffic from Mexico to prevent the importation, through accident or otherwise, of any Mexican cotton seed. It includes the inspection and disinfection of baggage, the cleaning or disinfection of all freight, express, and other shipments, except those which could not possibly carry infestation, restrictions on the entry of railway cars from Mexico, regulation of the transfer of freight, express, and other shipments, certification of all cars or other carriers of merchandise as a condition of entry into the United States (excepting merchandise or other materials of strictly local origin), and the cleaning of domestic cars as a condition of receiving freight originating in Mexico for movement into the interior of the United States.

The work in Mexico consists of cooperation with the Mexican Government and the planters to stamp out the pink bollworm in that country. The main infestation in the Laguna offers a hopeful opportunity for eradication on account of the loss which the pink bollworm has already shown itself capable of causing, and the fact that the cotton lands are owned by comparatively few persons. The other two infestations in Mexico are on individual ranches where it may be possible to have the planting of cotton abandoned for a series of years beginning with 1919. The work in Mexico also includes an investigation of the life history and habits of the pink bollworm with special reference to means of control.

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